# Evaluating Landscape-Scale Temporal Openings as a Management Tool to Maximize Catch Rates in Catch and Release Fisheries

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## Abstract

## Introduction

Catch rates are often cited as the primary determinant of satisfaction drawing anglers to fishing (Arlinghaus 2006). Consequently, catch rates are also a key rate that managers attempt to maximize. The actual rates in which fish are caught are dependent on a number of factors, including fish behavior, angler behavior, angler skill and abiotic factors such as weather and temperature. Obviously, only some of these factors can be indirectly controlled of managers.

Managers may try to manipulate aggregate catch and catch rates through a combination of fishing regulations aimed at altering angler behavior, effectiveness or likelihood of harvesting captured fish. Regulations are typically classed as either input controls, which limit where, when, and how many anglers are permitted to fish (e.g. time, area closures and limited entry harvest, respectively), or output controls, which limit the number and types of that can be harvested and the effectiveness in which they can be captured (e.g. bag limits, size limits and gear restrictions, respectively). Each of these regulation types has a set of specific uses for both achieving particular fishery objectives and for conservation.

Catch and release regulations are often used as a way of maintaining fishing opportunities in situations where harvest might lead to collapse or other conservation concern. Catch and release has gained prominence as a management tactic, with many anglers voluntarily releasing their catch. While releasing all captured fish helps reduce mortality and ensuring plenty of fish remaining to be captured repeatedly, there may be unintended consequences to catch and release. One such consequence is the frequent refrain that catch rates are lower later in the season. While this may be due to behavioural changes in fish as water temperature warms, this may also be due to fish being temporarily unreactive to fishing gear. This may be due to fish learning to avoid fishing gear or fish temporarily changing behavior as they recover from the experience or both. Catch and release regulations are typically only used in conjunction with temporary closures that protect particularly vulnerable times in the species life cycle, such as staging, spawning or nest guarding.

Fishing effort is often highest immediately after opening a fishery. This reflects a utility for above average catch rates.

If fishing utility is highest immediately following the opening of a fishery, and there is a exchange between vulnerability states, it may be beneficial to implement catch and release regulations with infrequent fishery openings across a landscape of discrete (small lake) fisheries. Doing so would theoretically attract fishing effort and maintain high catch rates on opening days while still provide sustainable fishing due to the lack of harvest. When implementing this strategy across multiple lakes, it may attract more effort than if all lakes were constantly open, while maintaining a higher mean catch rate across the season.

We propose using a series of short openings across a landscape of similar lakes managed as catch and release as a means of improving aggregate catch rates while not limiting access to fishing opportunities. Effectiveness of this management tactic will be evaluated through simulation and assumptions evaluated. Finally, we will discuss how to experimentally measure exchange rates, and how to set up the spatial opening tactic on a landscape fishery

## Methods

### Model development

The model assumes there are three primary states with respect to vulnerability to being captured: vulnerable, invulnerable and refractory. Vulnerable fish are in areas of the system where they are available to anglers and in a behavioural state where they will react to fishing gear. Invulnerable fish are not available to anglers because they are in an area of the system or a behavioural state where they will not be captured by anglers. Vulnerable fish that have been captured and released are in the refractory state, where they are unwilling to react to fishing gear even if they are otherwise available to be captured. These fish will eventually move into one of the other states.

The single lake model is described in Table 1; parameters and variables are given in T1.1 and described in Table 2. At the start of the year, the population is assumed to be in equilibrium, with no fish in the refractory state and fish in the vulnerable and invulnerable states dictated by the vulnerability exchange rates (Eq. T1.2-T1.4). Effort on any day is a logistic function dependent on expected catch per unit effort and scaled to the maximum effort. Realized effort will be the zero if the lake is closed to fishing on a particular day (*Ot*=0; T1.5). Abundance in each vulnerability state is updated daily by accounting for catches (T1.6), discard and natural mortality, exchange rates between states and appropriate allocation of recovered to vulnerable and invulnerable states (T1.7-T1.9).

The landscape model takes the model described above and accounts for multiple lakes at different distances to the angler population center (sensu Post and Parkinson 2012).

-landscape

Model evaluation

-elasticity (sensitivity)

-optimal openings (one lake)

-system performance (one lake, multiple lakes)

-seasonal/weather effects

## Results

## Discussion

Experimental setup

## Acknowledgements

## References

Table 1: Recreational fishery simulation model for a single lake.

|  |  |  |
| --- | --- | --- |
| Parameters | |  |
|  | T1.1 |  |
| Initial population | |  |
|  | T1.2 |  |
|  | T1.3 |  |
|  | T1.4 |  |
| State dynamics | |  |
|  | T1.5 |  |
|  | T1.6 |  |
|  | T1.7 |  |
|  | T1.8 |  |
|  | T1.9 |  |

Table 2: Notation for the recreational fishing model.

|  |  |  |
| --- | --- | --- |
| Symbol | Value | Description |
| Indices | |  |
| *t* | {1,2,…*T*} | Daily time step (T=36) |
| *l* | {1,2,…*L*} | Lakes (L=12) |
| Model parameters | |  |
| *N*0 | 1000 | Initial abundance of catchable fish |
| *q* | 0.05 | Catchability coefficient for recreational fishing gear |
| *v*1 | 2*t* | Vulnerable exchange rate into the vulnerable subpopualtion |
| *v*2 | 3*t* | Vulnerable exchange rate out of the vulnerable subpopulation |
| *Sr* | 0.9 | Survival following catch and release |
| *vr* | 0.2 | Vulnerable exchange rate out of the refractory subpopulation |
| *pv* | 0.5 | Proportion of fish leaving the refractory state that become vulnerable to the fishery |
| *C*0 | 0.5 | Base catch rate below which recreational anglers derive no satisfaction |
|  | 0.5,1,1.5 | Power parameter defining increase in satisfaction with catch rate |
| *C*50 | 3 | Catch rate attracting half of total available effort |
| *C* | 5 | Proportional to the rate at which effort increases with catch rate |
| *EWE* | 10 | Maximum effort on weekends |
| *EWD* | 10 | Maximum effort on weekdays |
| *Ot* | {0,1} | Opening switch across days of the year |
| Derived states | |  |
| *t* | 1/T | Daily time step |
| *Emax,t* |  | Maximum daily effort: depends on day of week and values *EWE* and *EWD*. |
| State variables | |  |
| *Vt* |  | Abundance of fish vulnerable to the recreational fishery |
| *It* |  | Abundance of fish invulnerable to the fishery |
| *Rt* |  | Abundance of fish recovering from catch-and-release |
| *E*t |  | Daily fishing effort (angler-days) |
| *Ct* |  | Total daily catch in the recreational fishery |

1-*pv*

*pv*

*pr*

1-e-*qEt*

Catch

Refractory fish

*R*

Stock available to anglers

*V*

Stock not available to anglers

*I*

*v*1

*v*2

*Sr*

1-*Sr*

Figure 1: Schematic representation of the recreational fishery with three states: vulnerable to fishing (*V*), invulnerable to fishing (*I*) and refractory (*R*). Exchange rates between vulnerable and invulnerable states are represented by *v*1 and *v*2. Catch on day *t* is proportional to effort on that day. All captured fish are released into the refractory state, from which they may die due to release mortality (1-*Sr*) or survive and leave that state at a rate of pr. Fish leaving the refractory state may return to the vulnerable state at a rate of *pv* or the invulnerable pool at a rate of 1-*pv*.



Figure 2: Elasticity of fishing value to changes in the key model parameters. Elasticity was calculated as the proportional change in value resulting from a 10% increase or decrease in the parameter value. Up-arrows represent value elasticity following parameter increases; down-arrows represent value elasticity following parameter decreases.



Figure 3: Barplots showing differences in key recreational fishery metrics (mean catch-per-unit-effort, total annual effort, total annual catch and value of the fishery) associated with different opening scenarios. Opening schedules associated with each scenario number are described in the legend.